



# Fetal Distress Insights from Cardiotocography Monitoring

**Dr. Roopa N K<sup>1</sup>, Likhith K S<sup>2</sup>, Meghana Y<sup>3</sup>, Pina Kiran S K<sup>4</sup> and Shreesha N J<sup>5</sup>**

Professor, Dept. of CSE, Sri Siddhartha Institute of Technology, Tumkur<sup>1</sup>

Students, Dept. of CSE, Sri Siddhartha Institute of Technology, Tumkur<sup>2-5</sup>

**Abstract:** The world's future relies on ensuring children are born without complications, yet many suffer from disorders like brain injury or stillbirth caused by fetal distress due to insufficient oxygen supply during delivery. Traditional Cardiotocography (CTG) is a widely used method to analyze the fetal heart rate (FHR) and the mother's uterine contractions. However, its interpretation is often subjective and dependent on clinician expertise, leading to inter- and intra-observer variation and high false-positive rates. This project addresses this critical gap by developing a more reliable, accurate, and automated system for monitoring fetal well-being using CTG data. The solution leverages machine learning (specifically, the Random Forest Classifier) and signal processing techniques to analyze key physiological parameters, aiming to reduce human error, standardize diagnosis, and provide real-time alerts for timely clinical interventions. Ultimately, this initiative seeks to enhance the quality and accessibility of prenatal care, contributing to better maternal and neonatal outcomes.

**Keywords:** Fetal Distress, Cardiotocography (CTG), Fetal Heart Rate (FHR), Machine Learning, Random Forest, Automation

## I. INTRODUCTION

The world's future relies on children, which is why it's crucial to ensure they are born without any complications or disabilities. Unfortunately, there are many new born infants who suffer from complex disorders like brain injury, cerebral palsy or even stillbirth caused by fetal distress, which occurs during delivery due to insufficient oxygen supply and other vital factors inside the mother's womb. To address this, medical professionals use car-diotocography, a widely used and effective method that analyses the fetal heart rate and the mother's uterine contractions. By analysing various fetal distress conditions and their possibilities, this method plays a significant role in identifying potential risks. Nowadays, though there are widespread uses of CTG, it suffers from inter- and intra- observer variation which results in false positives. During labor, both the FHR and uterine contractions are monitored carefully to assess the well- being of the toddler. Normal fetal heart charge patterns vary, however normally range among one hundred ten-one hundred sixty beats in keeping with minute (bpm) at some stage in the later stages of pregnancy and exertions.

Abnormal FHR styles, which includes bradycardia (low heart fee) or tachycardia (exces-sive coronary heart charge), can indicate fetal misery. Uterine contractions are monitored concurrently with FHR. This is important because contractions can now and again have an effect on the oxygen deliver to the fetus. Uterine contractions are normally represented as peaks or waves on the same graph. A regular FHR sample indicates variability, that means slight fluctuations inside the coronary heart fee over time, which is a sign of a healthy fetal fearful the unpredictability of these threats, manual monitoring is labor-intensive and prone to error. To address these challenges, the **"Innovative Solutions for Wildlife Conflicts Mitigation"** offers an automated solution using sensors, cameras, and AI. Ultrasonic and fire sensors detect motion and flames, while AI processes real-time camera data to classify threats. The system sends alerts via SMS, alarms, and LEDs, enabling timely farmer responses. It also includes motorized deterrents and operates on rechargeable batteries, ensuring continuous functionality even in remote areas. Automation reduces the need for constant human supervision, cuts labor costs, and improves threat response times. AI enhances system intelligence by learning from past events and distinguishing between harmful and harmless species. Beyond threat detection, the system supports wildlife conservation and environmental protection by reducing human-animal conflicts and crop fires. In essence, this system provides a scalable, cost-effective, and eco-friendly approach to safeguarding farmlands. It promoted sustainable agriculture by merging technology with practical design, ensuring greater productivity, safety, and ecological balance.



## II. METHODOLOGY

The project follows a systematic approach starting with data collection (FHR and UC signals) from reliable sources, leading into model training and implementation.

### Tools and Technologies Used:

- **IDE:** Visual Studio IDE
- **Language:** Python
- **Libraries:** NumPy, Matplotlib, WFDB package (Waveform Database), Pandas, Sklearn
- **ML Algorithm:** Random Forest Classified

### Functional Requirements:

- Accepts user input and gives the condition of the baby.
- Design and train a Random Forest classifier effectively.
- Predict the conditions with the best accuracy and display the outcomes.

### System Architecture

The overall system structure involves an input stage by Gynecologists or Obstetrics users, a login module, and an uploading file module<sup>49</sup>. The uploaded data is passed to the **Prediction** model, which outputs **Results** detailing the **Condition of the baby** and a **Graph visualization**<sup>50</sup>.

The core process flow (Data Flow Diagram - Level 1) is: **User Input (FHR and UC)**  $\rightarrow$  **Fetal Insights System**  $\rightarrow$  **Results (condition, graph)** to the User<sup>51</sup>. The system integrates medical expertise with real-time data processing to improve diagnostic accuracy<sup>52</sup>.

## III. OBJECTIVES

The project **Aim** is to develop an intelligent and automated system for detecting fetal distress through the analysis of CTG data to assist healthcare professionals in accurately monitoring fetal well-being.

The **Objectives** are:

1. Extract minimal features from recorded real-time CTG data (Fetal Heart Rate and Uterine contraction) and perform a diagnosis.
2. Classify the condition of the child based on Fetal Heart Rate and Uterine Contractions.
3. Provide better interpretation of the CTG data to give more confidence in providing an accurate diagnosis of a case

### Hardware Requirements:

The most common set of requirements defined by any operating system or software application is the physical computer resources, also known as hardware.

Hardware Components:

1. Ultrasonic Sensors
2. Fire Sensors (Flame, Heat, Smoke Sensors)
3. Cameras (Normal Night Vision)
4. Microcontroller (e.g., Arduino or Raspberry Pi)
5. GSM Module (for SMS alerts)
6. Buzzer / Siren
7. LED Indicators / Flashing Lights
8. Relay Module (for activating deterrents like sprinklers or lights)
9. Motion Detectors / PIR Sensors.

### Software Requirements:

Software requirement which is necessary for this project are

- **IDE:** Visual Studio IDE
- **Language:** Python
- **Libraries:** NumPy, Matplotlib, WFDB package (Waveform Database), Pandas, Sklearn
- **ML Algorithm:** Random Forest Classifier



#### IV. TESTING AND IMPLEMENTATION

The system is implemented as a **Flask-based web application** that classifies the fetal condition using the trained Random Forest model.

##### System Module Overview:

- **Login/Register:** User authentication for security.
- **Data Upload:** Uploads FHR and UC data in a predefined format.
- **Prediction:** Uses the trained Random Forest model to classify fetal condition.
- **Visualization:** Generates graphs for FHR and UC trends over time.
- **Output Display:** Shows results in a user-friendly interface.

##### Key Outputs:

- **Prediction:** Binary classification of the fetal condition as **"Normal"** or **"Risky"**.
- **FHR and UC Graphs:** For real-time interpretation.
- **Summary Report:** Includes mean, minimum, maximum FHR, and average contraction duration.

The implementation includes stages like a Homescreen, Login, and File Upload. The model is designed to solve the **class imbalance** problem to provide better generalization by employing strategies such as resampling and class weighting.

#### V. ADVANTAGES AND APPLICATIONS

##### Advantages:

The system's primary advantages stem from integrating **Machine Learning (Random Forest Classifier)** with Cardiotocography (CTG) data analysis:

- **Increased Accuracy and Reliability:** The automated system reduces the high false-positive rates and inter- and intra-observer variations associated with manual CTG interpretation. This leads to a more **accurate and consistent** diagnosis of fetal distress.
- **Reduced Human Error and Subjectivity:** The Random Forest model provides an **objective** analysis of Fetal Heart Rate (FHR) and Uterine Contraction (UC) patterns, eliminating reliance on a clinician's subjective judgment and experience.
- **Timely and Real-Time Decision Support:** The system can process data and provide a classification (**"Normal"** or **"Risky"**) much faster than a human, enabling **timely alerts** and interventions which are critical for preventing adverse neonatal outcomes like hypoxia or brain injury.
- **Efficiency and Resource Optimization:** The Random Forest algorithm is highlighted as requiring **less data to process** and offering **quicker data training** compared to other complex algorithms like KNN. This makes the system computationally efficient.
- **Accessibility in Underserved Areas:** By automating the interpretation, the system acts as a sophisticated diagnostic aid, making expert-level fetal monitoring more **accessible** in rural or under-resourced healthcare settings where specialists may not be readily available.
- **Better Interpretation:** The system provides **graph visualization** of FHR and UC trends, alongside the final predictive classification, offering a clearer, more comprehensive view to assist healthcare professionals in confirming the diagnosis.

##### Applications:

The system is designed to be applied in various healthcare settings to improve the efficiency and accuracy of fetal monitoring:

1. **Real-Time Fetal Monitoring during Labor and Delivery:**
  - The core application is providing **real-time, continuous monitoring** of Fetal Heart Rate (FHR) and Uterine Contractions (UC) during labor.
  - It offers **immediate classification** of the fetal condition as **"Normal"** or **"Risky"** to alert medical staff to potential fetal distress (e.g., hypoxia).
  - This is crucial for making rapid decisions regarding intervention, such as performing an emergency C-section, to prevent adverse neonatal outcomes.
2. **Diagnostic Aid for Healthcare Professionals:**
  - The system serves as an **intelligent decision-support tool** for gynecologists, obstetricians, and nurses.
  - By translating complex FHR and UC patterns into a clear, visual graph and a binary (Normal/Risky) prediction, it **assists in diagnosis** and increases the confidence of the medical team in providing accurate treatment.



3. **Enhancing Care in Resource-Limited Settings:**
  - The automation reduces the reliance on highly specialized staff for interpreting complex CTG data.
  - This makes **expert-level fetal monitoring accessible** in rural clinics, primary healthcare centers, or hospitals with limited resources, thereby improving maternal and neonatal care quality globally.
4. **Clinical Training and Education:**
  - The system's ability to clearly visualize FHR/UC graphs and link them directly to a diagnosis can be used as an **educational tool**.
  - It helps new medical practitioners quickly learn and understand the correlation between physiological signals and fetal well-being, enhancing their skills in CTG interpretation.
5. **Future Application: Remote Monitoring (Telemedicine):**
  - As noted in the future scope, the system can be expanded for **remote monitoring capabilities**.
  - This would allow high-risk pregnant women to be monitored from home, transmitting CTG data to the system for analysis and alerting healthcare providers of potential complications without requiring frequent hospital visits

## VI. CONCLUSION AND FUTURE SCOPE.

The system developed focuses on applying a classification technique in Gynecology and Obstetrics to predict normal and risky cases from CTG data. It helps pregnant women know the fetal distress of the baby, and easily determine the baby's condition during labor. The system translates FHR and uterine contraction data into a baby condition and provides graph visualization, which assists in diagnosis and treatment. The use of the Random Forest model enables quicker data training compared to other algorithms like K-Nearest Neighbors (KNN) and requires less data to process.

**Future Enhancement:** Future work can focus on several enhancements:

- **Numeric Classification:** Convert the baby's condition into numeric values, such as the percentage of distress.
- **Accuracy Improvement:** Increase the model's accuracy and try to solve the class imbalance problem for best results.
- **Advanced Monitoring:** Develop and integrate more sophisticated monitoring devices, like wearable sensors or AI-driven algorithms, to detect subtle signs of fetal distress earlier.
- **Telemedicine/Predictive Analytics:** Expand the use of telemedicine for remote monitoring, especially in underserved regions. Utilize machine learning to predict high-risk pregnancies.
- **Training and Education:** Develop Virtual Reality (VR)/Augmented Reality (AR) simulations for training healthcare providers in managing fetal distress scenarios. Create interactive educational tools for pregnant individuals.

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